Preliminary Investigation of CDTI and Procedures for Terminal Area In-Trail Spacing and Merging

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Study Objectives (1/2)

- Examine Pilot Ability to Perform In-Trail Spacing and Merging in the Terminal Area
  - Overall Issues
  - Display Requirements
  - Procedure Requirements

Expected to Benefit Efficiency and Safety and Serve as a Transition Mechanism to Free Flight

Study Objectives (2/2)

- Examine Interaction of Procedures and Displays
  - View Procedures as ‘Information Source’
  - View Procedures as Providing Structure

One Operational Concept Can Be Enabled by Many Different Procedures

  - *Some Can Be Better, “More Informative” Than Others*
  - *Display Requirements May Change With Procedures*

Procedures: A Broad Definition

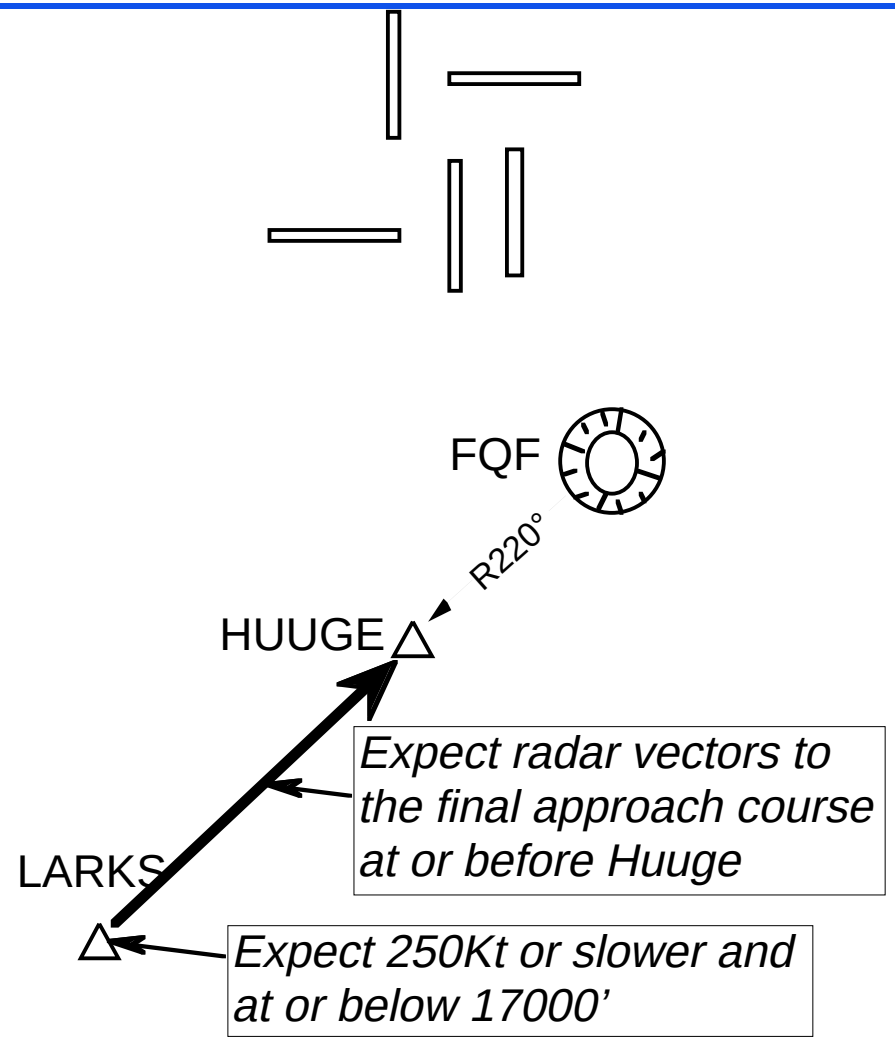
- "The Set of Prescribed/ Proscribed Actions Pre-Specified For Operators To Follow/ Avoid In Performing An Operation"
- Can Be Established In Different Ways
  - Laws
  - Regulations
  - Standard Operating Procedures (SOP)
  - Basis of Training and Testing
  - Unwritten Understanding

Information Content in ATM Procedures

- Requires Operator to Generate, Access, Update Information
- Constrains What Values ‘Information’ May Take
- Establishes Communications
- Creates a Shared Set of Knowledge and Expectations
  - Published
  - Unpublished

Information Pre-Specified by Procedures

- Published Procedures Drive Expectation of:
  - Aircraft's Behavior
  - ATC Actions
  - Actions of Other Pilots



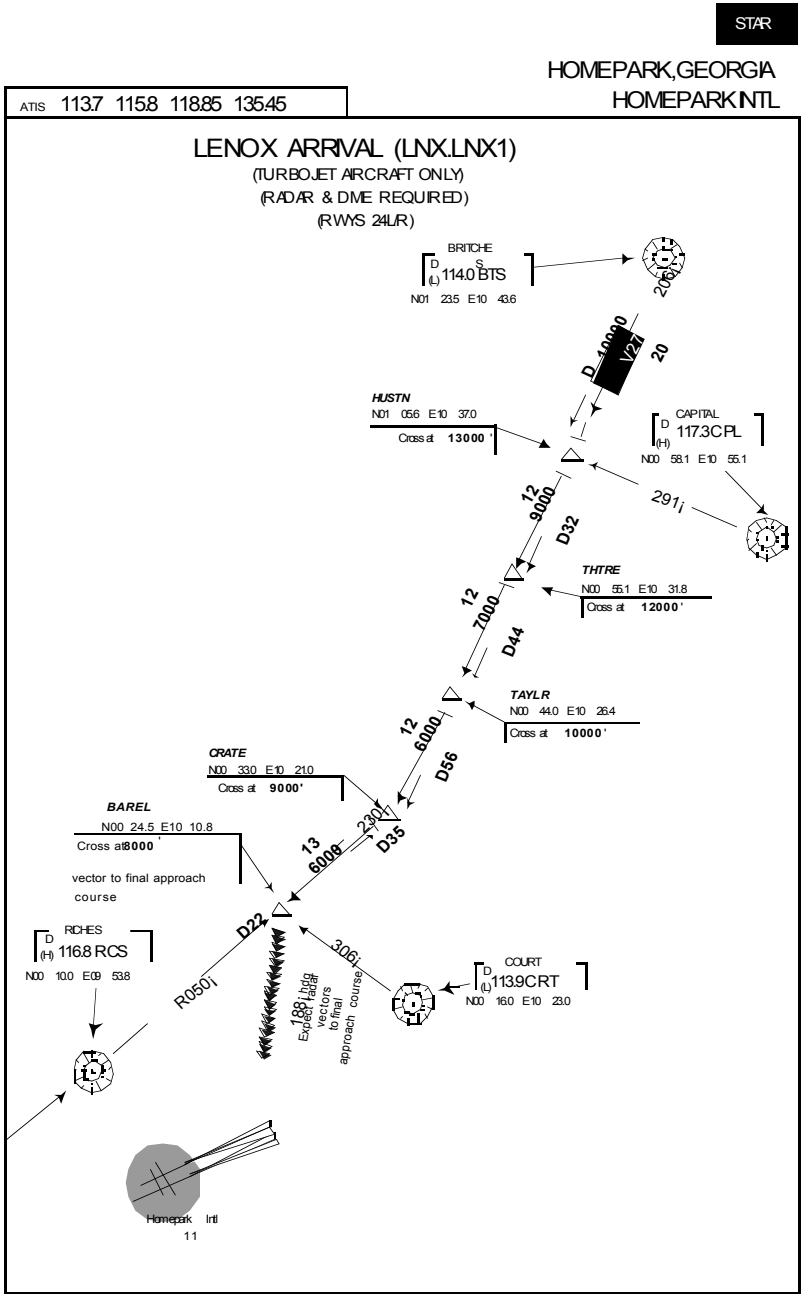
Overview of Experiment

- Airline Pilots ‘Flew’ Arrivals
  - Used Autopilot
  - Started at FL250, Ended at IAF
- During Arrival, Were Asked to Perform In-Trail Spacing and Merging
- Variety of CDTI and Procedures Were Tested

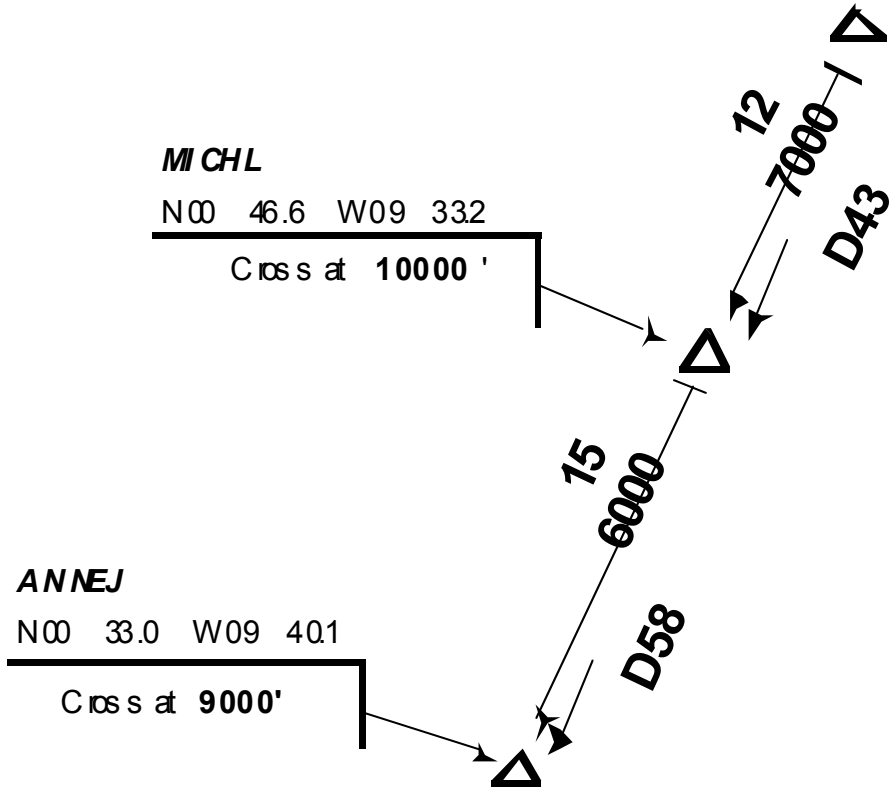
Flying the Arrival

- Pilot Issued In-Trail Spacing Distances From Controller
  - *"GT123, maintain 8 miles-in-trail behind BA557"*
- Pilot Issued Aircraft to Follow at Merge Point
  - *"GT123, cross behind QS221 at CRATE, maintain 4 miles-in-trail behind QS221"*
- No Speed Changes Were Issued by Controller

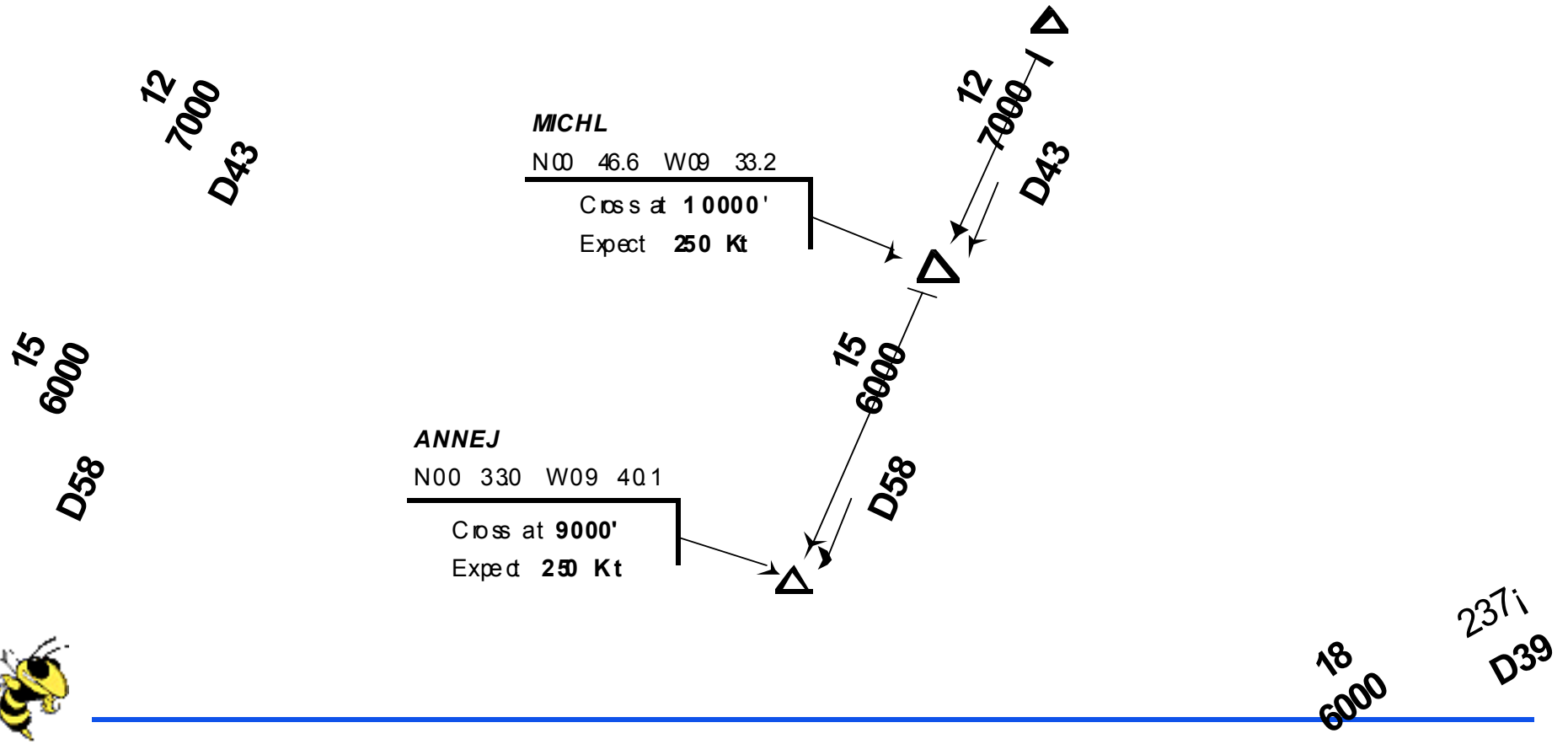
Standard Terminal Arrival Route (STAR)



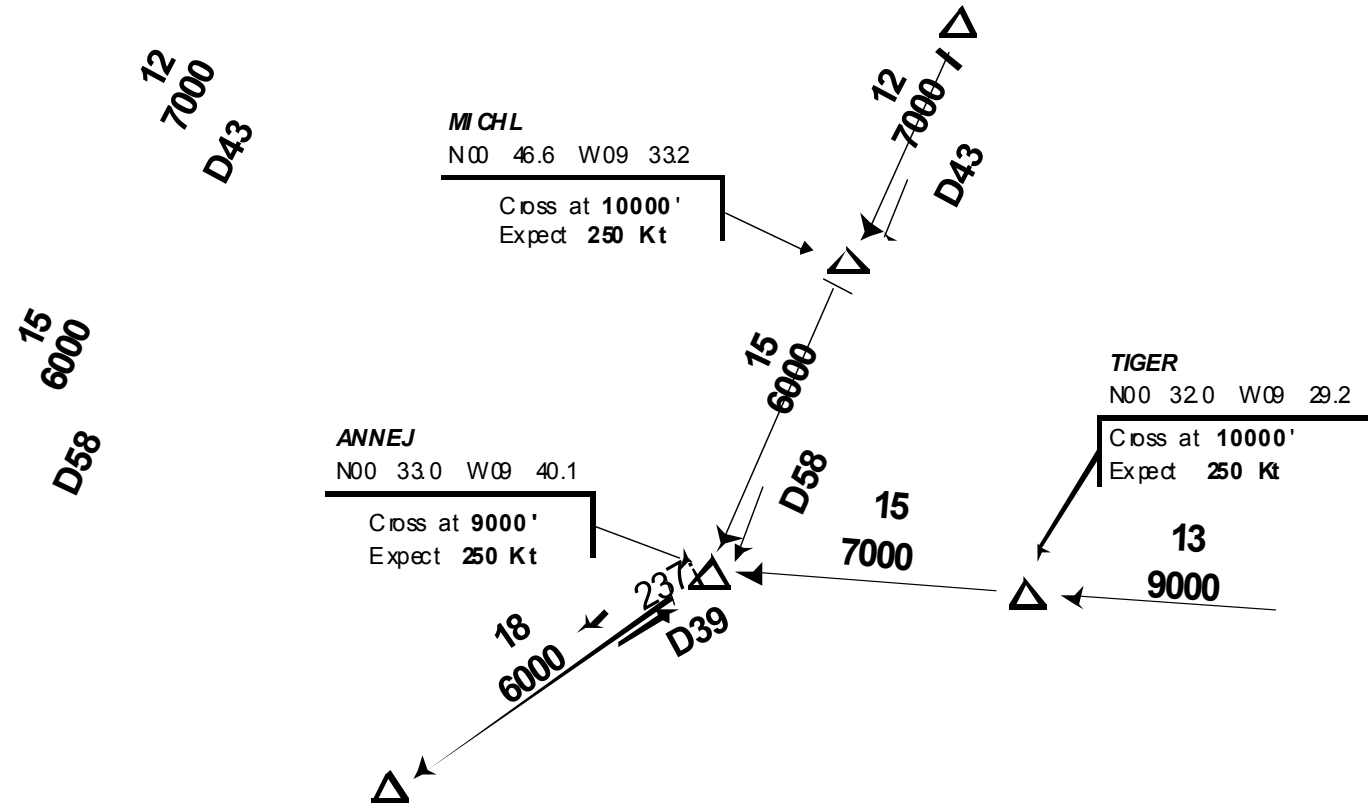
Detail From a 'Baseline STAR'



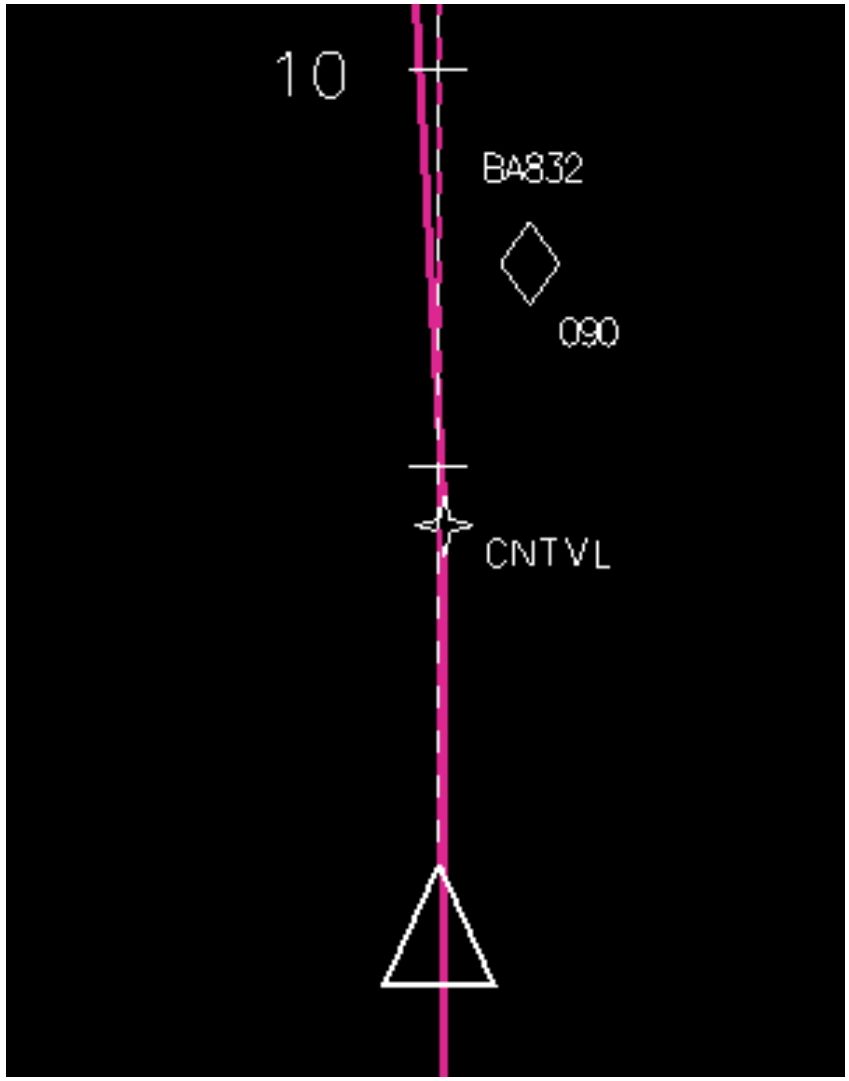
Detail From a 'STAR with Speed'



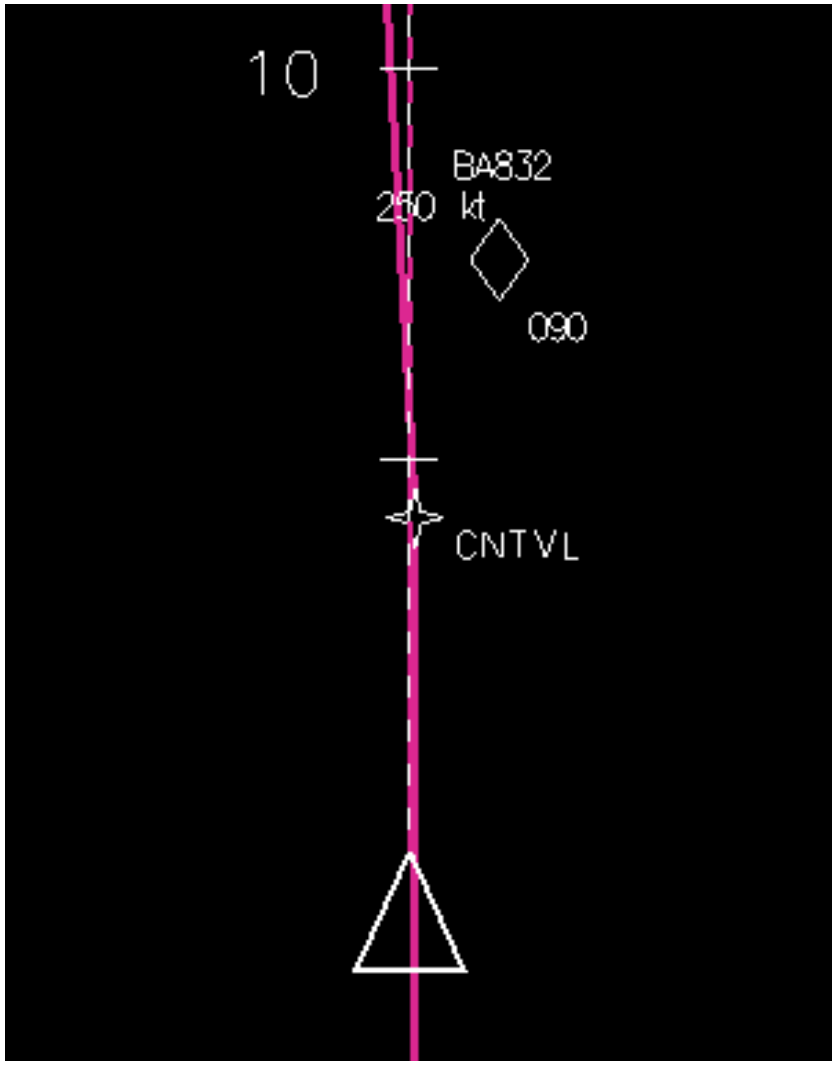
Detail From a 'STAR with Speed and Merging Path'



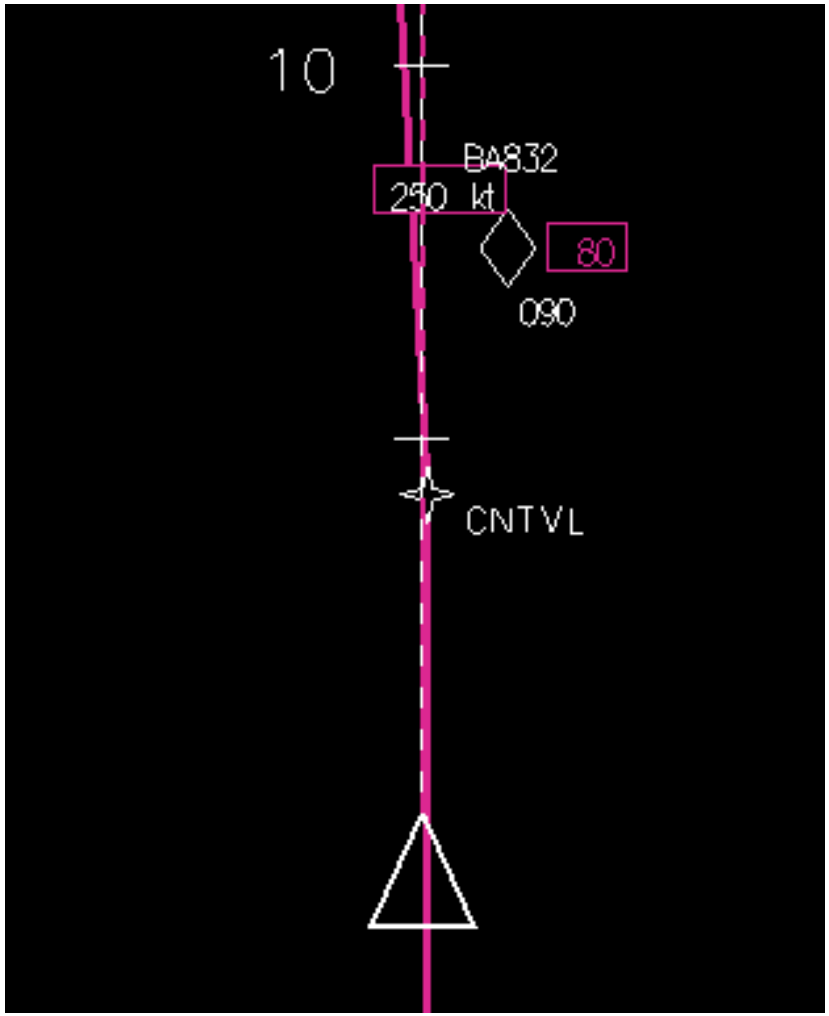
Baseline Display



Display with Speed



Display with Speed and Autopilot Targets

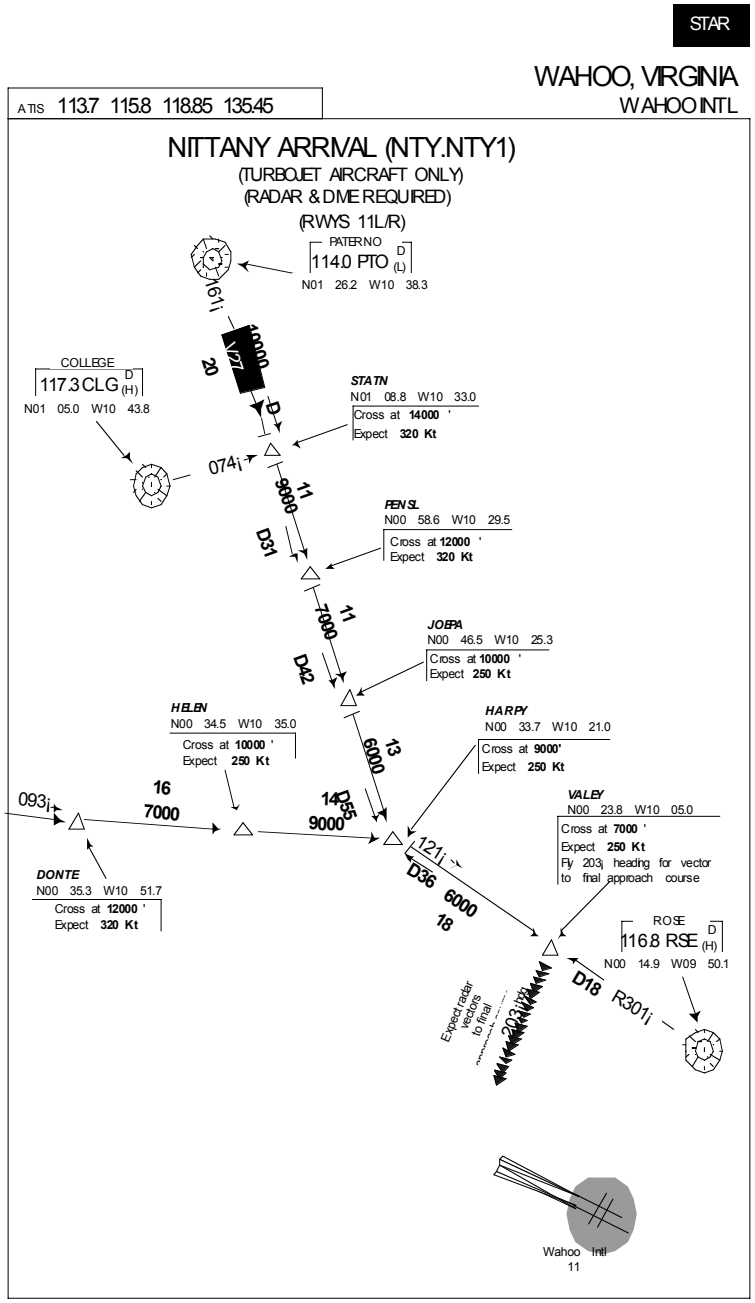


Primary Experiment

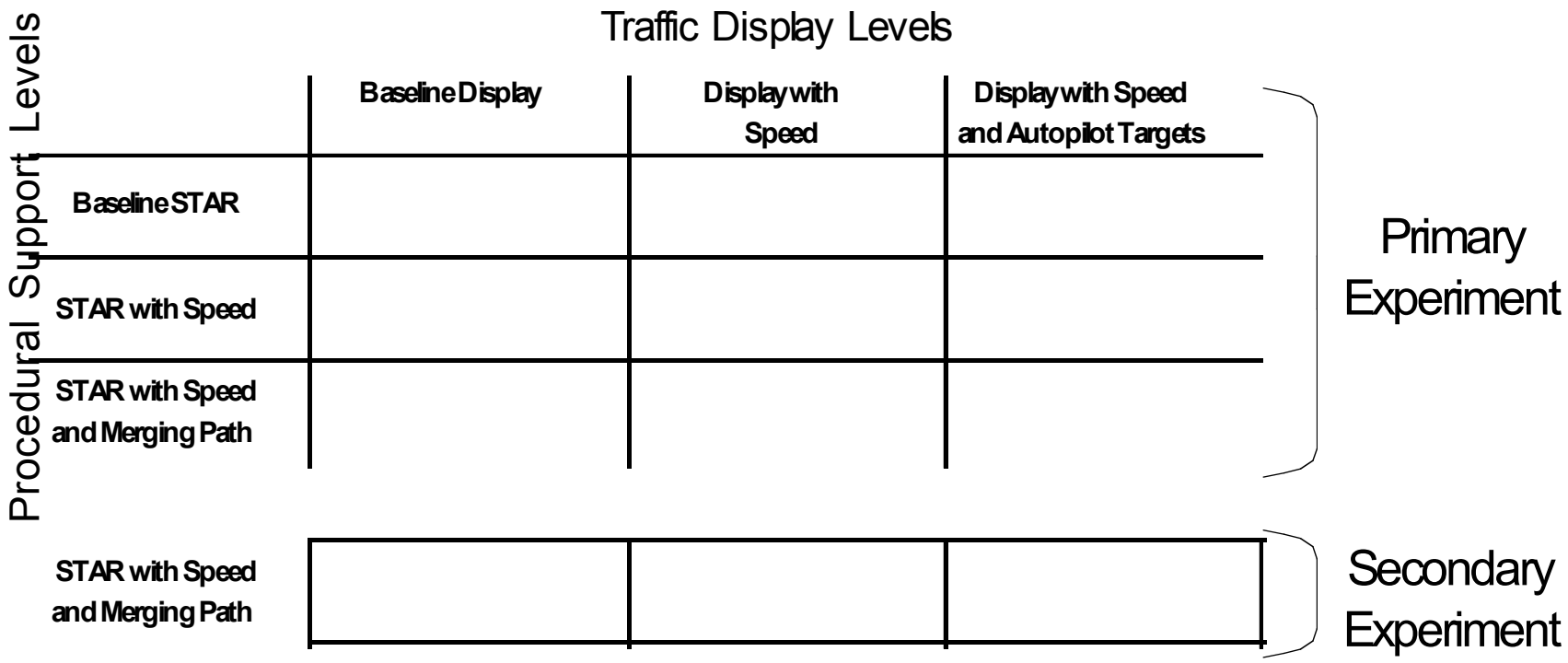
- All Aircraft Flew Expected Speeds
- All Aircraft Achieved Accurate In-Trail Separation Distances

Secondary Experiment

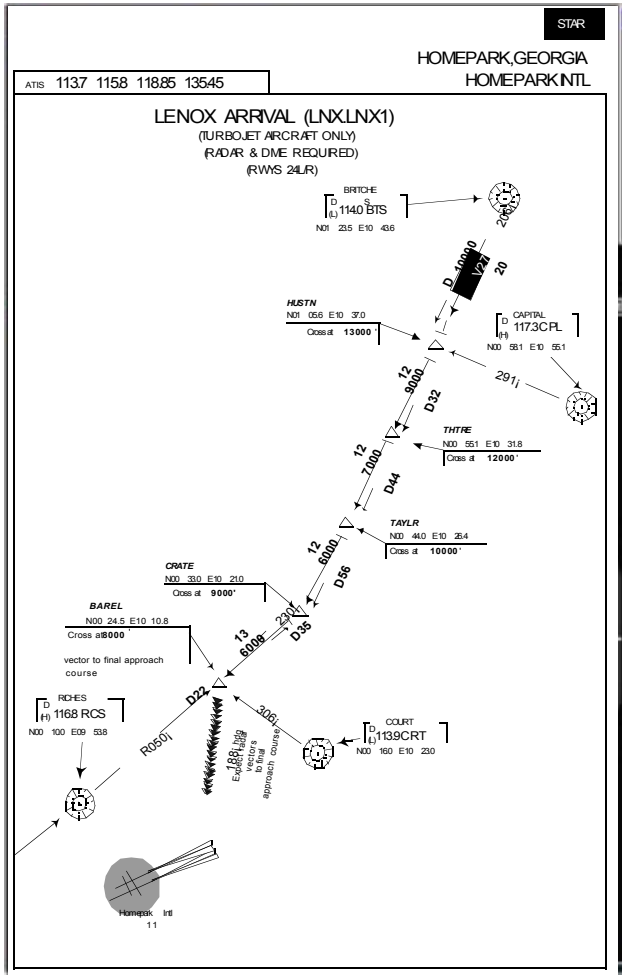
- Deviant Aircraft Flew Slower Than Expected Speed



Test Matrix


Traffic Display Levels
Procedural Support Levels
Baseline Display
Display with Speed
Display with Speed and Autopilot Targets
Baseline STAR
STAR with Speed
STAR with Speed and Merging Path
STAR with Speed and Merging Path
Primary Experiment
Secondary Experiment

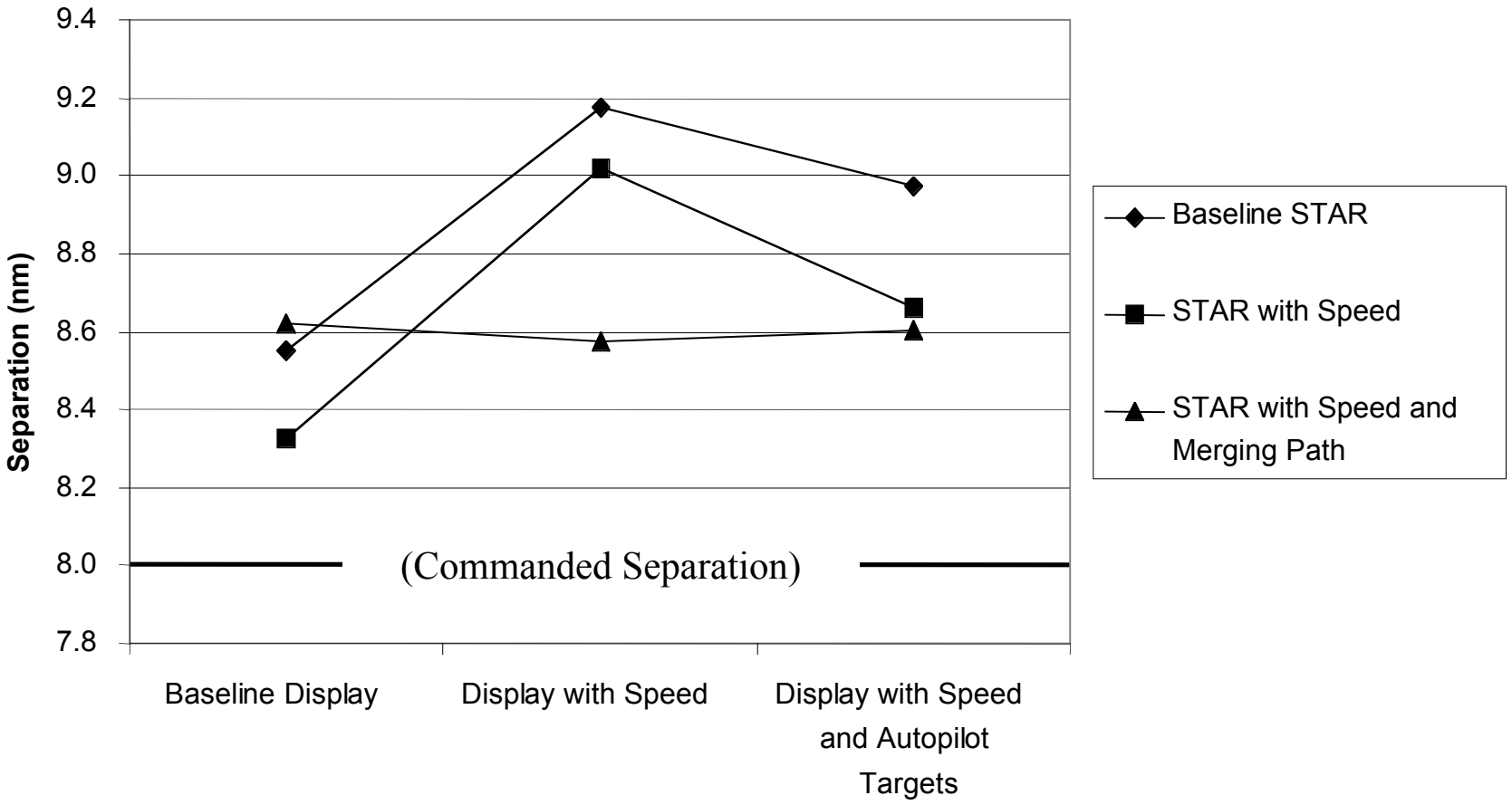
Display Panel



Subject Characteristics

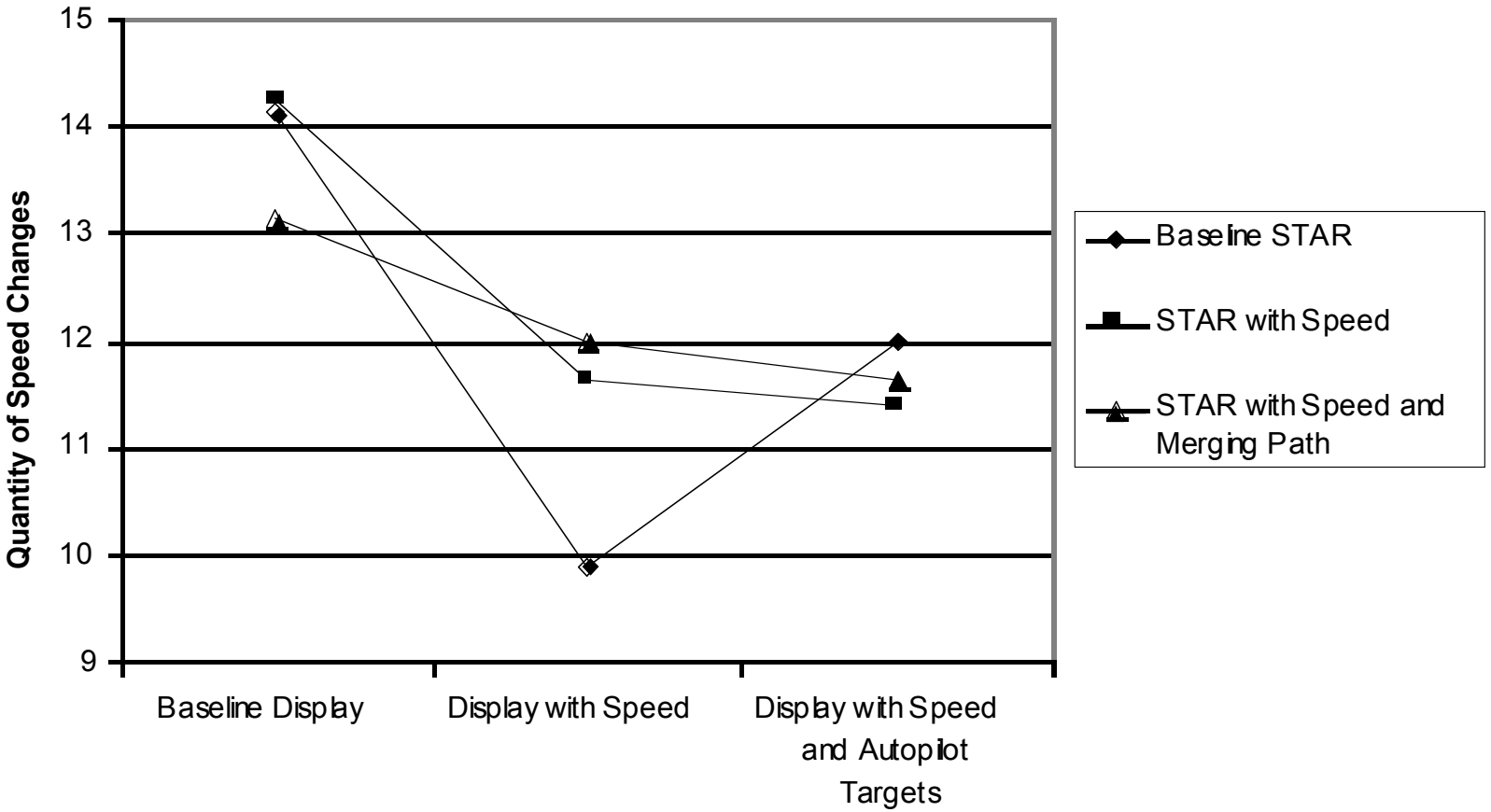
- 12 subjects - all male, all current airline pilots with a major airline
- Five captains, seven first officers
- Total hours ranged from 6000 to 16000 hours
- Ten subjects had experience in glass aircraft
- Subjects had flown Boeing 727, 737-800, 757, 767, MD80, MD88, and MD90

Average In-Trail Separation



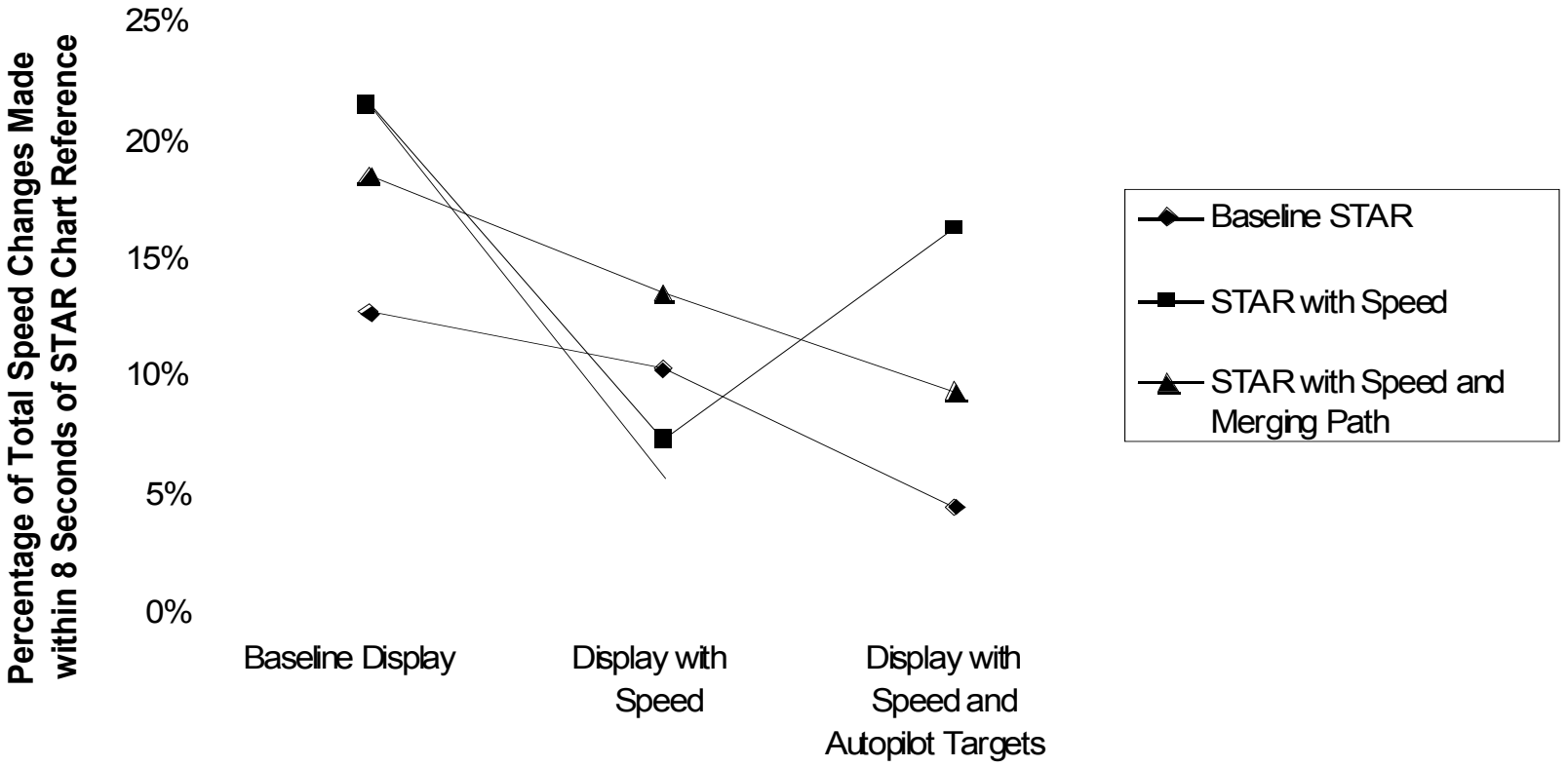
•Significant display/procedure interactions ($F=2.77$, $p<.04$)

Average Number of Speed Changes



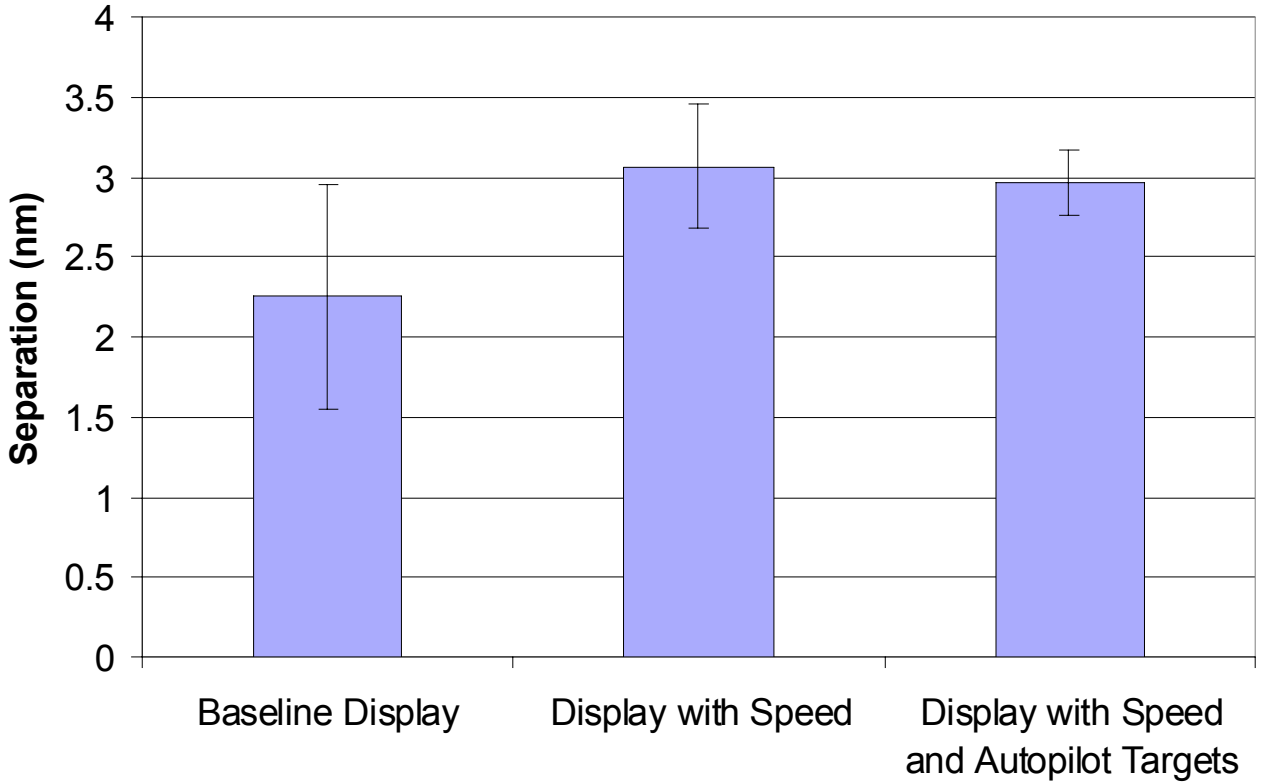
•Marginally significant display effects (F=2.83, p=.068)

Percentage of Total Speed Changes Made Within 8 Seconds of STAR Chart Reference



- Marginal effects due to displays ($F=3.06$, $p<.06$)
- Marginal effects due to procedures ($F=2.83$, $p<.07$)

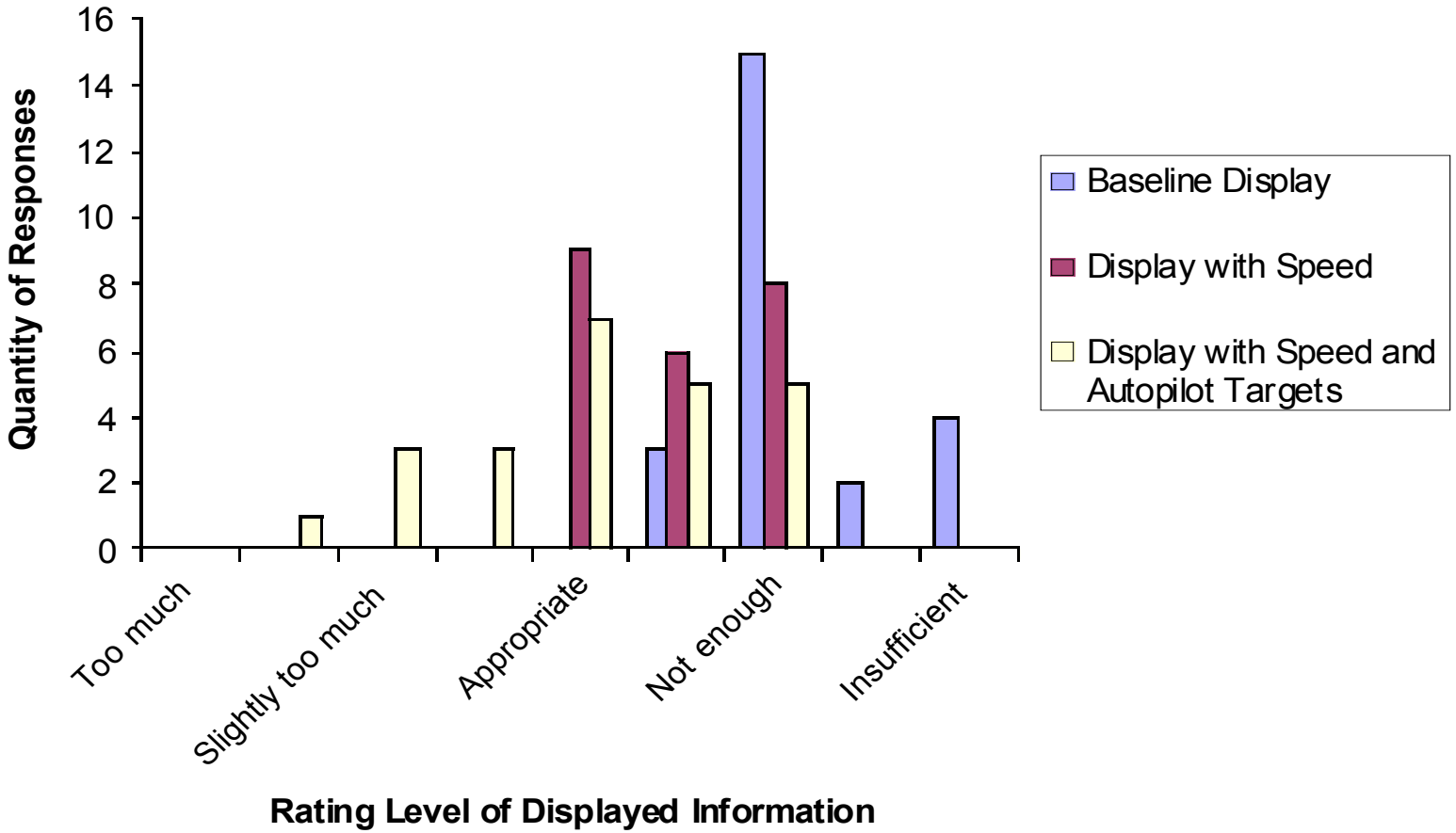
Deviant Scenario Average Separation



•Marginally significant display effects ($F=3.05$, $p=.10$)

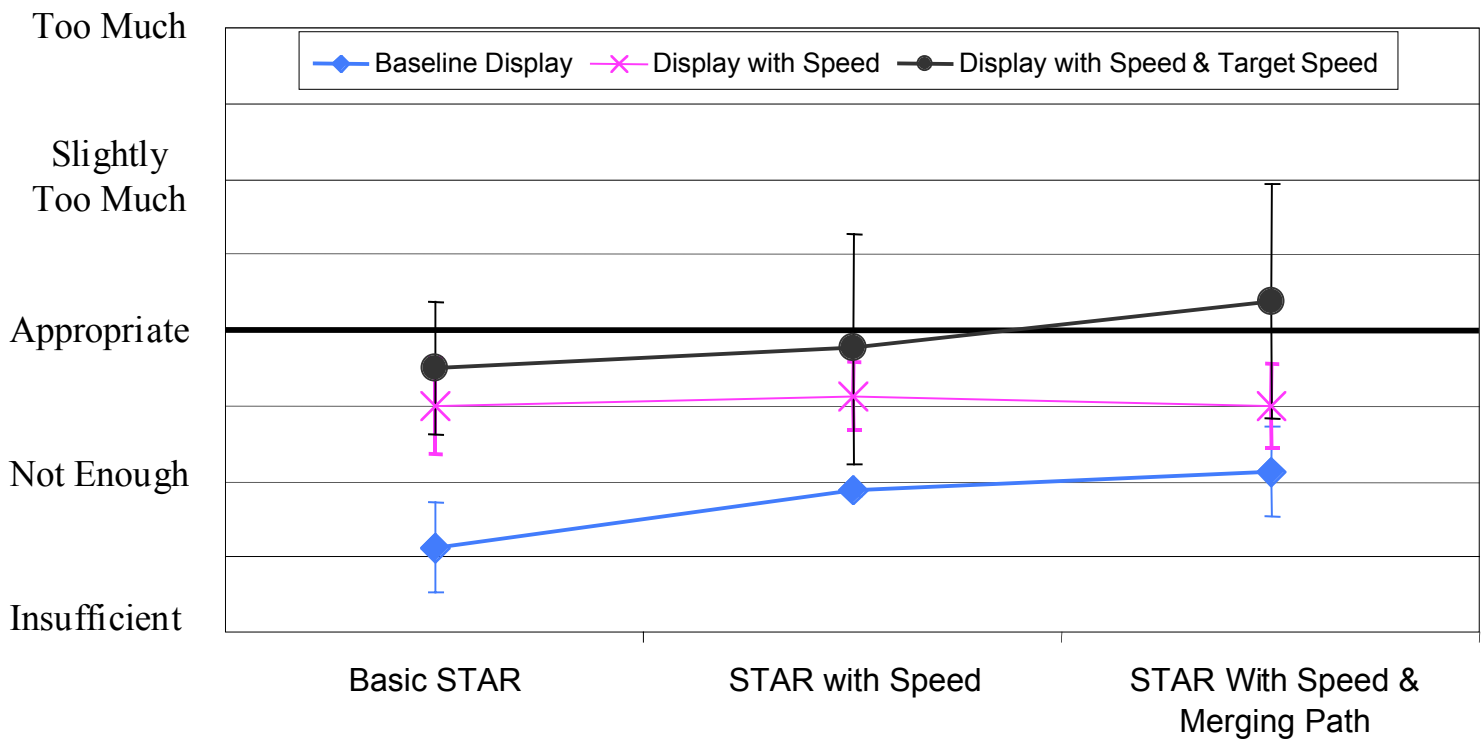
(Error Bars Reperesent σ)

Pilot Rating of Information Content



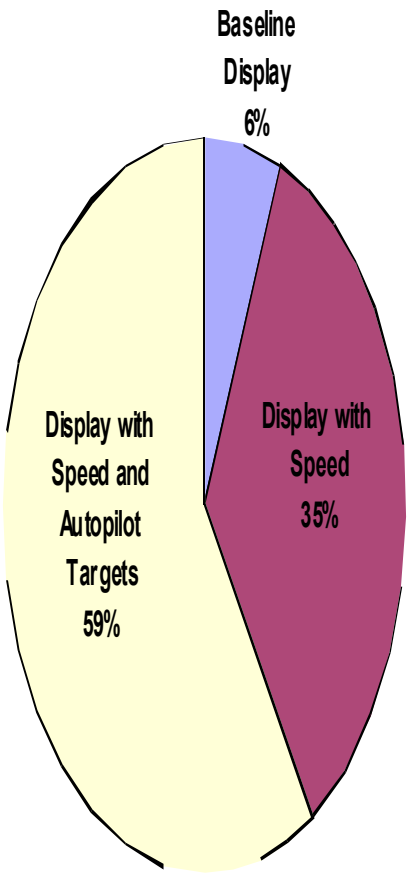
(n=71)

Ratings of Display Information

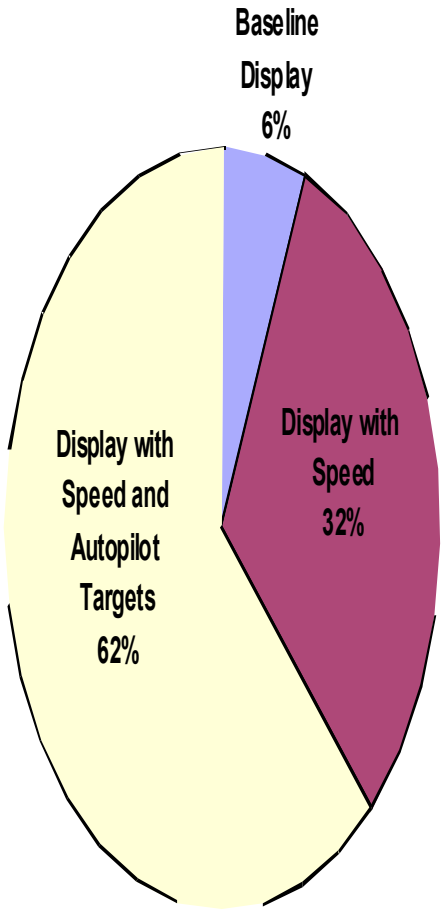


No Noticeable Change in Ratings Given in Deviant 7th Scenario

Which Display Provided Better Support for Maintaining In-Trail Separation?

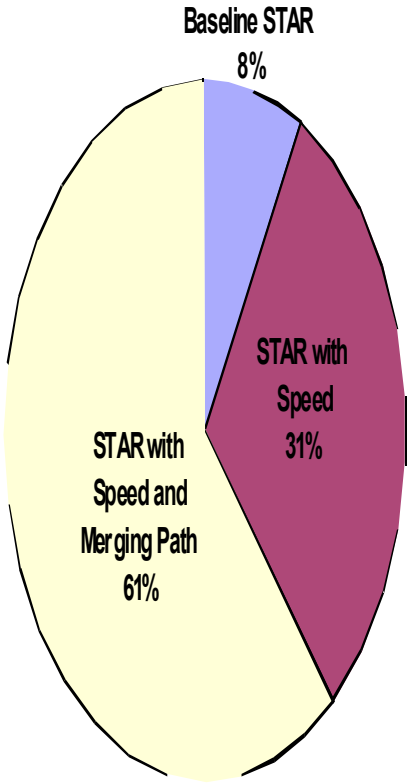


Which Display Provided Better Support for Merging with Another Arrival Stream?



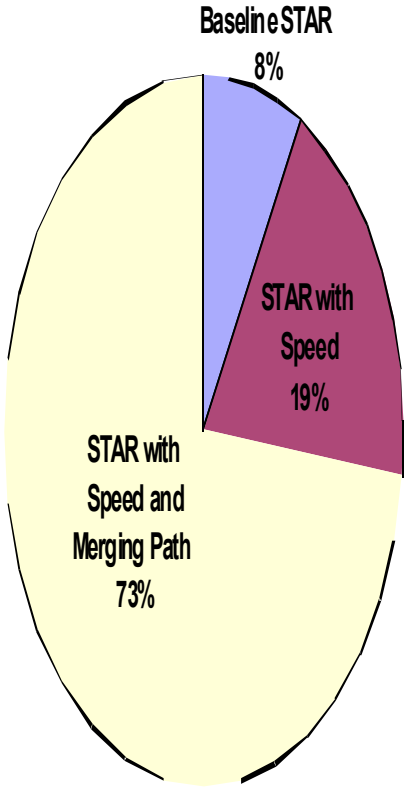
Which Procedure Provided Better Support for Maintaining In-Trail Separation?

- Strong Preferences for STARs with Speed over Baseline STAR



Which Procedure Provided Better Support for Merging with Another Arrival Stream?

- Strong Preference for STAR with Speed and Merging Path



Experiment Conclusions (1/2)

- Pilot-Performed Merging and In-Trail Spacing Worthy of More Detailed Research
- 11/12 Pilots Felt Pilot-Performed In-Trail Spacing Is Feasible
- Pilot Opinions on Merging Were Mixed
- Pilots Felt Strongly About Wanting Clearly Defined Role of Controller
  - Intervention Should Any Aircraft Not Follow Procedures
  - Responsible for Safety

Experiment Conclusions (2/2)

- Pilots Felt Clear Procedure Required for Anticipation of System Dynamics
- Pilots Appeared to Use Published Procedures as an Information Source
- Interactions Between Displays and Procedures Found Throughout Experiment
- Providing Robustness to Actions Not Anticipated by Procedures May Require More Emphasis on Displayed Information
  - May Even Be Viewed As A Role Of The Display!